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UTILIZATION OF SECONDARY POWER RESOURCES IN USSR METALLURGICAL ENTERPRISES

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/Tables are appended./

Metallurgical enterprises are large sources of secondary power resources which can be subdivided into two main groups: (1) combustible power resources (coke-oven and blast-furnace gas, coke breeze, intermediate products, and tar from gas-generator stations), and (2) physical heat of flue gases, cooling water, metallurgical furnace slags; also, the heat of finished products, e.g., metal, refractory parts, coke, etc.

Modern metallurgical enterprises equipped during the Stalin Five-Year Plans have, in addition to improved production technology, a high degree of utilization of combustible power resources. However, at many enterprises, especially old ones, there are considerable possibilities for increased utilization of internal power resources, especially physical heat, the utilization of which is still on a low level.

Heat-Balance Structure of Ferrous Metallurgy Plants and the Significance of Secondary Power Resources

The significance of secondary power resources in the over-all power balance of metallurgical plants, the extent to which they are utilized, and prospects for their further utilization are examined below on the basis of a large modern plant with a complete metallurgical cycle.

Table 1 gives data characterizing the yield of secondary power resources and their utilization in the main shops of a metallurgical plant. It shows the annual heat yield of secondary power resources, the utilization of heat from secondary resources at the present time, and also its possible utilization after the introduction of shop-tested heat-recovery installations, and after carrying

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out scientific research work and industrial trial of the measures scheduled for adoption. Secondary power resources are subdivided into combustible power resources and physical heat.

As can be seen from Table 1, the sources of combustible resources are the blast-furnace shop, providing 34.9%, and the coke and chemical shop, providing 19.5% of the total secondary power resources of the enterprise. The total quantity of combustible power resources is 57.3%. The physical heat amounts to 42.7%, the greatest quantity of secondary heat being in the open-hearth furnace. The amount of physical heat which can be utilized at present is very limited and amounts to 8%. Thus a very small part of the physical heat is utilized.

The installation of heat-recovery equipment can raise the amount of utilizable heat to 15%; after industrial testing the heat utilization can be raised to 26%. Thus, complete heat utilization at a modern, large metallurgical plant can result in a considerable economy in conventional fuel.

Table 2 gives data on the yield and utilization of individual types of secondary power resources at the metallurgical plant under examination.

As can be seen from Table 2, the heat from the blast-furnace gas amounts to 33.5% and the heat of the coke-oven gas amounts to 15.9% of the total secondary power resources. Thus, efficient distribution and burning of the combustible gases is one of the main problems.

The physical heat of the flue gases is considerable, the total for all shops amounting to 19.4% of the total yield of power resources for the plant. At present, this heat is utilized to a negligible extent in the rolling shop only, where 3.4% is used by employing the heat of the gases in recuperators.

By increasing the utilization of heat for preheating gas and air, and also by introducing waste-heat boilers, the heat recovery of the combustion products can be increased, at present, to 6.3%. The maximum heat utilization can be increased to 9.4% by using waste-heat boilers in conjunction with recuperators, installed after the high-temperature heaters.

The heat of red-hot coke amounts to 5.2%. According to experimental data, utilization of the heat of red-hot coke can amount to about 3.6% by using chambers for the dry slaking of coke, with subsequent utilization of the heat formed in waste-heat boilers.

The heat of cooling water, which amounts to 4.9% of the total yield of secondary power resources, is not yet utilized.

As the experimental work shows, up to 80% of this heat can be used, or 4.1% of the total yield. Most of this comes from the open-hearth furnace shop, where 2.8% can be utilized. One percent comes from the blast-furnace shop and 0.3% from the rolling shop.

The heat of molten slag comes to 6%.

Experimental work on utilization of slags being carried out at present points to the possibility of recovering up to 70% of the heat they contain. Thus, it can be supposed that the usable heat of slags amounts to 4.2% of the total yield of power resources.

At the plant under consideration, the amount of physical heat obtainable in the metallurgical shops is 42.7% of the total yield of power resources. Eight percent is used at present.

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The example given shows that the main methods of improving the utilization of secondary power resources giving the greatest economical effect are (1) efficient utilization of blast-furnace and coke gas, (2) use of waste-heat boilers to utilize the heat of open-hearth furnace flue gases, and recuperators to utilize the heat of heating furnaces and also the heat of dry slaking of coke, which amounts to 24.6% of the total yield of secondary power resources; and (3) utilization of the heat in cooling water (4.9%).

At present much importance is attached to this work.

It should be noted that the plant examined is characteristic of enterprises equipped during the first and second Five-Year Plans. Old plants are distinguished by poorer utilization of secondary, in particular combustible, power resources. Enterprises being designed and equipped at present, are marked by the high technical level of power engineering and utilization of secondary power resources (including physical heat) to the maximum possible extent.

Heat-Balance Structure of Nonferrous Metallurgy Plants and the Significance of Secondary Power Resources

Nonferrous metallurgy plants also have considerable sources of secondary power resources, including both combustible resources and physical heat. In contrast to ferrous metallurgy plants, the combustible gases have a very low heat value. There are combustible resources at a relatively small number of enterprises.

Table 3 gives data characterizing the yield of secondary power resources and their utilization at one plant.

As can be seen from Table 3, the main source of secondary power resources is the melting shop which gives 98.4% of the total yield of power resources. Thus, work on utilizing secondary heat must be concentrated in one shop, in contrast to ferrous metallurgy plants where work on heat utilization must be carried out simultaneously in all the main shops.

The total amount of combustible power resources in the heat of flue gases of water-jacketed furnaces is fairly large and amounts to 44.2% of secondary power resources. These gases are not used, and their utilization presents considerable difficulties as the calorific value of flue gases does not as a rule, exceed 400-500 kg cal/cu m hour. At the same time, efforts are made, when operating the furnace, to ensure that the CO in the exhaust gases is at a minimum.

The utilization of combustible gases can be considered possible only after scientific research and experimental work in this direction has been carried out.

Of secondary power resources, 55.8% is contained in physical heat. At present, the quantity of heat used is negligibly small and comes to 0.52% in all, although methods of using a considerable portion of the physical heat have been sufficiently assimilated. By fitting heat-recovery equipment, it is possible to utilize up to 11% of the total yield of heat in secondary resources and up to 34.8% after carrying out scientific research work and industrial application.

Thus, nonferrous metallurgy plants have great opportunities in using physical heat. Table 4 shows data on the yield and utilization of individual types of secondary power resources at the plant under examination.

As can be seen from Table 4, the heat contained in liquid slags is the largest of the physical-heat components (23.7%). Although slag heat is not used at present, experimental work now being successfully carried out in this direction gives grounds for supposing that it will be possible to start equipping industrial installations in the near future. Utilization of this heat amounts to 16.6% of the total yield of power resources.

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A second large quantity is the heat of the flue gases of water-jacketed furnaces (20.47%). Their utilization does not offer any great difficulty and will be possible after fitting heat-recovery equipment. The expected saving is 10.2%.

A considerable quantity of heat can be obtained by utilizing the cooling water of water-jacketed furnaces, which will be able to give 7.26% of the total heat yield in secondary resources.

Thus, the main tasks in utilizing secondary power resources at nonferrous metallurgy plants are (1) to find methods of using the chemical heat of the flue gases of water-jacketed furnaces; (2) utilization of the heat in slags; (3) utilization of the heat in cooling water; and (4) utilization of the heat in the waste gases of the melting shop.

State and Prospects of Physical-Heat Utilization

Heat of flue gases in used for the needs of (1) open-hearth furnaces, copper-melting, and pipe-welding furnaces, and gas motors /for induced-draft fans?/ for obtaining steam in waste-heat boilers; (2) furnaces of the heating, continuous, chamber, and other types for heating air and gas in recuperators and regenerators; and (3) reverberatory furnaces for drying concentrate and tunnel ovens for drying brick, etc.

Metallurgical furnaces are large consumers of fuel, and therefore, reduction of heat losses is especially important in their case.

Heat losses in the flue gases of open-hearth furnaces amount to 25-35%. When the temperature of the gases leaving an open-hearth furnace is reduced from 500-600 to 200-250°C, 15-20% of the heat can be used in waste-heat boilers, which corresponds to a yield of 0.30-0.35 ton of steam for one ton of steel melted in the furnace.

The heat lost in the flue gases of reverberatory and pipe-welding furnaces amounts to 35-60%. When waste-heat boilers are installed, 25-40% of the heat put into the furnace can be saved and used to produce steam.

At present, 44 waste-heat boilers, with a maximum output of about 150 tons of steam per hour, are installed at 18 metallurgical plants. The annual steam output of these boilers is over 500,000 tons.

Fourteen of these boilers are fitted to reverberatory furnaces, 15 to pipe-welding furnaces, 11 to gas motors, three to open-hearth furnaces, and one to gas generators. They are divided into the following types: flue, fire tube, horizontal water tube, vertical water tube, and forced circulation.

Thus, experience has shown that all the main designs of boilers can be used as heat-recovery equipment.

Installations fitted with waste-heat boilers operate on various fuels: coal, mazut /fuel oil/, blast-furnace gas, and a mixture of coke-oven and blast-furnace gas.

Most waste-heat boilers have a low steam output. The average load of the installed boilers is not more than 3.5 tons/hr. However, individual boilers fitted to copper-melting furnaces have a steam output up to 12 tons/hr. There are also waste-heat boilers with an output of 2 tons/hr. The boilers work at a steam pressure of 5-17 atm.

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Waste-heat boilers are fitted to furnaces with an initial gas temperature of 550 to 1,300°C. Some boilers operate under conditions where the heat load varies considerably. For example, when they are fitted to reverberatory furnaces the temperature of the gases varies from 700 to 1,250°C. The degree of cooling of gases in waste-heat boilers is fairly high; with an initial gas temperature of 550-700°C, the temperature of the flue gases is 160-180°C, and when the initial temperature is 700-1,300°C, the temperature of the flue gases is not usually more than 300-320°C, which corresponds to a boiler efficiency of 50-70%.

Waste-heat boilers work an average of 7,000-7,500 hr a year. Thus, the degree of utilization of the boilers is fairly high, amounting to 0.82-0.87, which is greater than the coefficient of utilization of ordinary boilers fitted in industrial fire rooms. The quantity of steam produced by waste-heat boilers at individual plants is 100,000 tons a year.

Each waste-heat boiler gives a yearly fuel saving of at least 1,000 tons of conventional fuel. The fuel saved by using large waste-heat boilers amounts to 5-10 million tons of conventional fuel a year.

According to the data of individual plants, the cost of one ton of steam in a waste-heat boiler is less than that of steam obtained from the plant boilers. The installation of waste-heat boilers pays for itself in 1.5-2.5 years.

Extensive introduction of waste-heat boilers is being retarded by the absence of the necessary equipment. Mass production of these boilers is a priority task for heavy machine-building enterprises.

The installation of recuperators for preheating air and gas for high-temperature heating furnaces is of great technical and economic significance. With a mean flue-gas temperature of about 800-1000°C, and air heated to 400°C, the fuel saving is 25-40%. Heating the air raises the furnace temperature and enables coke-oven gas to be replaced by blast-furnace gas in many cases. For high-temperature furnaces, working on mixed gas, heating the air allows the calorific value of the mixture to be reduced. For example, if working on cold air requires mixed gas with a calorific value of 2,500 kg cal/cu m, which corresponds to 50% of coke-oven gas in the mixture, heating the air to 400°C enables the coke-oven gas content to be reduced to 35%, i.e., by almost a third.

At present, 18 furnaces are fitted with recuperators. Recuperators are fitted to compartment kilns, continuous furnaces, and heating furnaces. Cast-iron needle recuperators are most commonly used, being fitted to 14 furnaces; tubular recuperators are fitted to four furnaces.

At one plant, the fitting of needle recuperators to a billet furnace not only resulted in a fuel saving but also enabled the furnaces to be changed over to blast-furnace gas.

The cost of manufacturing and installing recuperators on four furnaces was about 40,000 rubles, and the yearly fuel saving is 140,000 rubles. Fitting recuperators thus paid for itself in 3.5 months.

At another plant, the expenditure of conventional fuel after the installation of needle recuperators in a heating furnace was reduced by 16.5%.

In a continuous furnace working on hot air, some of which was heated in an independently heated recuperator, a supplementary tubular recuperator was fitted to heat the air delivered to the lower jets (35-40% of the total air delivered to the furnace). Although the air was heated to a comparatively low temperature (250°C) and there were several defects in manufacture, the installation of a tubular recuperator resulted in a fuel-consumption reduction of 5.5%.

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In 1948, the production of cast-iron needle recuperators was organized at the Ufaley Plant of Glavmashmet (Main Administration of Metal Machine Building, Ministry of the Metallurgical Industry). Casting recuperators of modified cast iron with a 1.5-2% chrome content was mastered in a very short time. This type of cast iron can be machined without any special difficulties; modification lowers the hardness of cast iron considerably. Although the heat resistance of low-alloy cast iron increases slightly, the addition of chromium noticeably decreases oxidation, whereas oxidation of ordinary cast iron is progressive.

The plant has also mastered the casting of recuperators from heat-resisting silicon cast iron. Melting this type of cast iron in a cupola furnace is not difficult, and its heat resistance differs little from that of cast iron with a high chromium content.

Heat Utilization of Furnace-Flue Gases for Technological Purposes

In addition to using the heat in flue gases by employing waste-heat boilers and recuperators, some plants are working on utilizing flue gases without using special equipment.

A coil steam superheater for heating steam used for fuel atomization at the sprayers has been installed at one plant in the smoke flue of a continuous oil-fired furnace. This measure gives a 2% fuel saving.

At the same plant, the open-hearth furnaces designed to operate on gas are presently working on mazut as a temporary measure. In 1948, the plant connected a gas nozzle in parallel with the air nozzle to heat the air. This gave a yearly saving of about 1,000 tons of mazut or 4.5% of the yearly fuel consumption.

The exhaust heat of tunnel stoves for drying brick has been utilized at chamotte plants.

At several plants, the heat from the exhaust gases of ten reverberatory furnaces is used to dry flotation concentrates.

Heat Utilization in Cooling Water and Slags of Metallurgical Furnaces

The heat in the cooling water of open-hearth furnaces can be used by raising the temperature 80-90% and then using it for district-heating purposes, or by evaporating it in the cooling system and using the steam obtained for power purposes.

Experiment work now being carried out in this direction by Giprostal' (State Planning Institute for the Steel Industry) is of considerable interest. Molten slag from metallurgical production, having a temperature of 1,100-1,300°C, contains a considerable quantity of heat, and, therefore, recovery of this heat is of importance. The heat of molten slag is used at various metallurgical plants.

A large-scale experimental installation for utilizing the heat in slag from an electric furnace was set up in 1947. The slag is cooled to 100°C in a heat-recovery installation. The coefficient of recovery of slag heat in the apparatus is about 80%.

As soon as the apparatus is started, the heating boilers are shut down and all the heating is changed over to hot water from the recovery apparatus. On the basis of data obtained from the experimental installation, an industrial installation is being designed.

At one plant, heat from the slag of three rotary furnaces is used to heat air. The slag temperature is 700-800°C and the quantity is 4,500 tons a month. The air is blown through the slag bunkers of the rotary furnaces by means of fans and is thus heated to 300-400°C. During 8 months of 1948, utilization of the heat in slag saved 1,000 tons of fuel.

Supplying heated air to the rotary furnaces, besides saving fuel, assisted in speeding up the technological process.

Energotsvetmet (Power Administration of the Nonferrous Metallurgy Industry) has completed an installation for recovering the heat in slag by means of a water-jacketed furnace.

Utilizing Heat From Dry Slaking Coke

The first industrial installation for utilizing heat from dry slaking coke was made at Kerch Coke and Chemical Plant, where it worked until 1941. It consisted of two compartments for dry slaking coke and four flue compartments which generated 3.5 tons of steam per hour at a pressure of 14 atm. White-hot coke, loaded into the coke-slaking compartment at a temperature of 850-950°C, was cooled there to 250-275°C. The gas, passing through a layer of coke is heated to 550-700°C and is then cooled in the boiler to 170-200°C.

According to data obtained from experiments carried out by the Scientific Research Gas Institute, the specific yield of steam is about 400 kg for every ton of coke loaded into the compartment.

Dry slaking of coke has the following advantages over the damp method: (1) obtaining steam suitable for power purposes, in quantity sufficient to satisfy the demands of coke and chemical plants; (2) decreasing the waste of small coke and increasing the yield of large coke; (3) the abolition of coke-tunnel water-supply arrangements (pump, settling tank, etc.); and (4) improvement of the hygienic conditions of labor.

The renewal of experimental work in this direction is of great interest.

Main Conclusions and Tasks

1. During the Stalin Five-Year Plans, a great amount of work has been done at metallurgical enterprises on improving the technical level of power economy, including the improvement of fuel-power resources. At the same time, utilization of internal resources by plants is still far from complete. In particular, much work must be done on utilizing physical heat; priority attention should be given to this problem.

2. The main tasks in the utilization of physical heat at enterprises of the metallurgical industry are: (a) maximum use of waste-heat boilers for metallurgical furnaces; (b) the use of needle and tubular recuperators for heating air and gas for the furnaces; (c) utilization of the heat in slag and cooling water; (d) utilization of the heat in dry-coke slaking.

3. Utilization of secondary power resources at metallurgical enterprises could be improved considerably if the Ministry of Heavy Machine Building would satisfy demands which have been made to it more than once by the metallurgical industry.

In the course of the next few years, the Ministry of Heavy Machine Building should organize the production of waste-heat boilers for open-hearth, copper-melting, and zinc furnaces, cast-iron needle recuperators for metallurgical furnaces, and other heat-recovery equipment.

4. Planning, and scientific research organizations must carry out further work on maximum utilization of all kinds of wasted heat, reducing the use of external fuel to a minimum, and achieving greater efficiency in fuel balance.

/Appended tables follow./

Table 1

Utilization of Heat in Conventional Fuel

Name of Shop	Ann Heat Yield in Conventional Fuel (%)	At Present	After Fitting Heat-Utilization Installations (%)	After Carrying Out Sci Research Work and Industrial Testing of Equipment (%)
	Combustible Power Resources			
Coke - chemical	20.1	19.5	19.5	19.5
Blast furnace	37.2	34.9	34.9	34.9
Open hearth	--	--	--	--
Rolling	--	--	--	--
Total	57.3	54.4	54.4	54.4
	Physical Heat			
Coke - chemical	8.6	--	--	5.1
Blast furnace	10.3	2.4	3.4	5.2
Open hearth	16.0	2.2	7.4	9.8
Rolling	7.8	3.4	4.2	5.8
Total	42.7	8.0	15.0	25.9
Grand total	100	62.4	6[illegible].4	80.3

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Table 2

Utilization of Heat in Conventional Fuel

Name of Shop	Ann Heat Yield in Conventional Fuel (%)	At Present (%)	After Fitting Heat-Utilization Installations (%)	After Carrying Out Sci Research Work and Industrial Testing of Equipment (%)
		Combustible Power Resources		
Coke breeze and small coke				
Coke - chemical	4.2	4.0	4.0	4.0
Blast furnace	3.8	3.7	3.7	3.7
Coke oven	15.9	15.5	15.5	15.5
Blast furnace	33.5	31.1	31.2	31.1
Total	57.3	54.4	54.4	54.4 [sic]
		Physical Heat		
Heat of incandescent coke	5.2	--	--	3.6
Heat of flue gases				
Coke - chemical	3.4	-	--	1.5
Blast furnace	3.7	--	--	--
Open hearth	4.9	--	2.4	2.4
Rolling	7.4	3.4	3.9	5.5
Heat of cooling water				
Blast furnace	1.1	--	1.0	1.0
Open hearth	3.4	--	2.8	2.8
Rolling	0.4	--	0.3	0.3
Heat of liquid slag				
Blast furnace	2.6	--	--	1.8
Open hearth	3.4	--	--	2.4

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Table 2 (Contd)

Utilization of Heat in Conventional Fuel

Name of Shop	Ann Heat Yield in Conventional Fuel (%)	At Present (%)	After Fitting Heat-Utilization Installations (%)	After Carrying Out Sci Research Work and Industrial Testing of Equipment (%)
		Physical Heat		
Heat of metal				
Blast furnace	2.9	2.4	2.4	2.4
Open hearth	4.3	2.2	2.2	2.2
Total	42.7	8.0	15.0	25.9
Grand total	100	62.4	69.4	80.3

Table 3

Name of Shop	Ann Heat Yield (%)	At Present (%)	After Fitting Heat-Utilization Installations (%)	After Carrying Out Sci Research Work Industrial Introduction (%)
	Combustible Power Resources			
Melting	44.2	--	--	37.50
		Physical Heat		
Melting	51.2	1.4	10.64	34.44
Annealing	0.32	--	0.24	0.24
Reduction	1.34	0.12	0.12	0.12
Total	55.8	0.52	11.0	34.8
Grand total	100	0.52	11.0	72.3

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Table 4

Name of Shop	Ann Heat Yield (%)	At Present (%)	After Fitting Heat-Utilization Installation (%)	After Carrying Out Sci Research Work and Industrial Introduction (%)
		Combustible Power Resources		
Waste gases from water-jacketed furnaces	44.20	--	--	37.50
		Physical Heat		
Heat of waste gases				
Melting	20.47	--	10.24	10.22
Reduction	1.18	0.12	0.12	0.12
Annealing	0.20	--	0.16	0.16
Heat of cooling water				
Melting	9.10	0.04	0.04	7.26
Heat of liquid slag				
Melting	23.70	--	--	16.6
Metal and matte				
Melting	0.87	0.36	0.36	0.36
Reduction	0.16	--	--	--
Annealing	0.12	--	0.08	0.08
Total	55.8	0.52	11.00	34.80
Grand total	100	0.52	11.00	72.3

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